STUDENT PAPER*

Certain Aspects of the Armstrong Regeneration, Superregeneration, and Superheterodyne Controversies

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SUMMARY

EDWIN H. ARMSTRONG OBTAINED PATENTS and reaped financial reward from them for his contribution of regenerative, superregenerative, and superheterodyne radio circuits. Claims in each of these patents were later held invalid on the ground of priority of invention by others. Armstrong has been honored by professional groups and shares the social and historical credit for his contributions in these fields.

INTRODUCTION

THE CONSTITUTION OF THE UNITED STATES PROVIDES that Congress has the power "To promote the progress of science and useful arts, by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries." [1] Unlike the laws of many foreign countries which grant patents to the first inventor who files an application, the American patent law requires that a patent be granted to the first who conceives an invention and is then diligent in reducing it to practice.[2]

Since conception is essentially a subjective matter, the tribunals charged with determining who is the first inventor have a very difficult task which may be complicated by extremely technical subject matter. The patent controversies of Edwin H. Armstrong, perhaps as none other, illustrate these problems.

Edwin H. Armstrong, born December 18, 1890, devoted his adult life to advanc-

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[1] U.S. Const., Art. 1, Sec. 8.

[2] 35 USC 102 (g).

ing the radio art as an inventor, author, and professor of electrical engineering at Columbia University. Forty-three patents [3] have been issued naming Armstrong as inventor. Much of his life, which ended in a tragic suicide on February 1, 1954, was spent in very involved, protracted and taxing litigation concerning among others, his patents on the regenerative circuit,[4] the superheterodyne radio receiver,[5] and the superregenerative circuit.[6] At the time of his death, Armstrong was engaged in sixteen separate infringement suits on a number of his frequency modulation patents. Four more were filed after his death.[7] Five of these suits were dismissed on stipulation and one was tried, the court finding Armstrong's patents valid and infringed.[8]

A biography on Armstrong was published in 1956;[9] the author, Lessing, boldly claims that Armstrong was the true inventor of the regenerative circuit, the superheterodyne radio, and the superregenerative circuit. This paper is devoted to a brief review of some aspects of the legal controversies involving Armstrong's patents on these circuits. Further, an analysis is made of claims that Armstrong is recognized as the true inventor of these circuits.

THE SUPERHETERODYNE CONTROVERSY

By 1917, the radio receiver art had progressed a long way from the day that Marconi first invented the radio. Pickard had devised a crystal detector, De Forest had invented the triode tube, and amplifiers using triode tubes were being used to amplify weak radio signals.

The heterodyne principle was being used to receive radio signals.[10] The principle can be observed and illustrated by causing two tuning forks, such as those used in piano tuning, to vibrate at the same time at different rates. A "beat" note, the difference between the rates of the individual tuning forks, can be heard. As used in the radio art, the heterodyne principle involved the reception of a high frequency radio signal which was "mixed" with another signal of frequency very close to that of the received signal in a non-linear device, such as the crystal rectifier. The result, analogous to that occurring when the outputs of two tuning forks are "mixed" in the human ear, was a beat frequency electrical signal, the difference between the two high frequency signals. The difference frequency signal was within the audio range and could be used to energize earphones or loudspeakers thus giving an audible indication of the presence of a received radio frequency signal.

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[3] See Appendix A.

[4] Patent No. 1,113,149, issued Oct. 6, 1914.

[5] Patent No. 1,342,885, issued June 8, 1920.

[6] Patent No. 1,424,065, issued July 25, 1922.

[7] See Appendix B for a listing of the suits filed on the frequency modulation patents.

[8] Armstrong v. Emerson Radio and Phonograph Corporation, 123 *USPQ* 133, 179 Fed. Supp. 95 (S.D.N.Y. 1959).

[9] Lessing, *Man of High Fidelity: Edwin Howard Armstrong* (Philadelphia and New York: J. B. Lippincott and Company, 1956).

[10] See Patent No. 1,544,081 filed Jan. 2, 1907, issued June 30, 1926.

One of the greatest problems in the radio art which existed at this time was the limitation of the triode tube in radio receivers as an amplifier of high frequency signals. As the frequency became higher, the tube became more and more inefficient. It was to this problem that Armstrong, who was then in France serving in the Army, addressed himself in March of 1918.

Armstrong, knowing that the triode tube could not effectively amplify high frequency radio signals, perceived that if means could be found to reduce the frequency of a radio signal in a receiver before amplification and detection, a greatly improved receiver would result. Using the heterodyne principle, Armstrong provided a non-linear device in which he "mixed" a received high frequency radio signal with a second high frequency signal which he generated in the receiver. The first and second signals when "mixed" provided a difference or "beat" signal, not of audio frequency as in known heterodyne receivers, but of a radio frequency lower than the frequency of either the first or second signals. The "beat" signal so produced was readily amplifiable in the triode tube. After amplification the signal was detected in a conventional detector, such as a crystal rectifier. The output of the detector was an audio frequency which could be used to drive earphones or a loudspeaker.

This invention, which came to be called the superheterodyne receiver, was destined to become one of the greatest advances in the radio art. Today, over forty years later, the superheterodyne principle is used in virtually all radio and television receivers, has wide use in radar, navigation equipment, and many military applications.

Armstrong filed an application on the superheterodyne circuit on February 8, 1919, and received a patent on June 8, 1920.[11] While Armstrong's application was pending, an application for a similar receiving system was filed by Lucien Levy, a French inventor whom Armstrong had met in France. After Armstrong's patent had been issued, Levy copied the claims.[12] The primary examiner refused to allow Levy to make the claims. The principal issue was a simple one. Figure 7 of the drawing in Levy's application included two possible modifications disclosed in dotted lines. One of the modifications disclosed the use of amplifiers for amplifying a heterodyne signal of inaudible frequency, the other a source of a second high frequency signal at a receiving station, rather than a source remote from the receiving station which was also disclosed. In order to make the claims both modifications must exist simultaneously, but Levy's specification lacked any explicit teaching that both could be used at the same time or that any advantage would result from such an arrangement. The Board of Appeals and the Commissioner affirmed; Levy appealed to the Court of Appeals for the District of Columbia, which reversed the Commissioner.[13]

Accordingly, an interference was declared; on opening the preliminary statements, it was found that the earliest date of conception alleged by Armstrong

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[11] Note 5, *supra*.

[12] Except for minor subcombination claims 4 and 5 which Armstrong lost in Interference No. 45,783 and appear respectively in Patent No. 1,508,151 and No. 1,734,132.

[13] In re Levy, 2 F.2d 939, 55 App. D.C. 138 (1924).

was March 1918, later than the French filing date of August 4, 1917, to which Levy was entitled. Armstrong made a motion to dissolve on the ground that Levy's specification did not support the counts, that is, the copied claims; it was denied. Levy filed a motion for judgment; Armstrong responded with a motion for leave to take testimony bearing on the right of Levy to modify his disclosure in order to make Armstrong's claims. The motion was denied and judgment entered for Levy; the Commissioner affirmed. Armstrong appealed; and the District Court of Appeals Affirmed.[14] In due course Levy's patent was issued.[15]

The Court quoted with approval from the decision of the Law Examiner ". . . it requires no inventive extension . . . to provide a basis for the simultaneous use of heterodyne reception and amplification . . ." It is likely that the court probably meant that it could be implied from the Levy disclosure that both modifications could be made at the same time.

While the result of the decision here was to deny Armstrong the distinction of being recognized legally as the first inventor of the superheterodyne receiver, he did not suffer financially for he had sold his superheterodyne and regeneration patents to the Westinghouse Electric Company on October 5, 1920, for $335,000.[16]

THE REGENERATION CONTROVERSY

By 1912, a mere six years from the time that De Forest had invented the triode vacuum tube, many inventors were working on devices which used his invention. De Forest was investigating the use of the new device in low frequency telephone circuits. Armstrong, then a young college student, was addressing himself to the problems of using the triode in high frequency radio receiving circuits.

During the fall of 1912, according to Armstrong, he developed an improved amplifier for high frequency radio signals. He filed a patent application on the device on October 29, 1913, and in due course was granted a patent.[17]

In August of 1912, De Forest, seeking to use triode tubes as a two way repeater for audio frequency signals, interconnected the input and output circuits of a triode and observed that the device would "sing"; that is, produce musical tones.

Armstrong, perceiving a new use for the regeneration phenomenon which he had observed in developing his improved amplifier, filed an application on December 18, 1913, for an oscillating circuit based on the regenerative principle. De Forest filed applications on aspects of the use of his vacuum tube in feedback arrangements on March 21, 1914, and on September 23, 1915. The three applications were placed in interference with others, which had been submitted by two other well known inventors, Langmuir and Meissner.

During the pendency of the interference proceeding, Armstrong sued, in the Southern District of New York, the De Forest Radio Telephone and Telegraph

[14] Armstrong and Levy, 29 F.2d 953, 58 App. D.C. 293 (1929).
[15] Patent No. 1,734,038, issued November 5, 1929.
[16] Lessing, note 9, *supra*, p. 131.
[17] Note 4, *supra*.

Company for infringement of his amplifier patent. The defense of prior invention by De Forest was rejected and the Armstrong amplifier patent sustained.[18] The Circuit Court of Appeals affirmed [19] finding that De Forest had not understood the true nature of his experiments in 1912. The Supreme Court denied a petition for certiorari.[20] Final judgment was not entered in the infringement suit.[21] Had final judgment been entered, the doctrine of *res judicata* may have been applicable in later suits.

Meanwhile, the Commissioner of Patents, affirming the Interference Examiners and the Board, awarded priority to Armstrong in the four party interference on March 31, 1923. De Forest appealed to the Court of Appeals for the District of Columbia which reversed the Commissioner,[22] but observed in doing so that they were not passing on the invention involved in the New York infringement suit.[23] In due course two patents were issued to De Forest.[24] The interference battle continued in the District Court of Delaware where the three unsuccessful parties filed bills in equity under the provision of Section 4915, Revised Statues.[25]

De Forest, knowing that the decision in the New York infringement suit [26] was not *res judicata,* filed suit in the District Court of Pennsylvania under Section 4918, Revised Statutes [27] to have Armstrong's tuned regenerative amplifier patent [28] declared invalid. The court ruled in favor of De Forest.[29]

The result reached by the Pennsylvania court in declaring claims invalid in the Armstrong patent, which had been sustained in the infringements suit, was based largely on the doctrine of *Morgan* v. *Daniels,*[30] where the Court held that, as to priority of invention, the decision of the Patent Office in interparte cases must be controlling unless the contrary is established by testimony which in character carries thorough conviction. Thus the court considered that the Armstrong radio frequency detector-amplifier invention was the same as the invention claimed by De Forest. One could hardly expect a different result, since Westinghouse and Armstrong had insisted that only one invention was involved,[31] in spite of the fact that Armstrong's initial position in the Patent Office was that

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[18] Armstrong v. De Forest Radio Tel. and Tel., 279 Fed. 445 (S.D.N.Y. 1921).

[19] Armstrong v. De Forest Radio Tel. and Tel., 280 Fed. 584 (C.C.A. 2d Cir. 1922)

[20] De Forest Radio Tel. and Tel. v. Armstrong, 270 U.S. 663, 46 Sup. Ct. 471 (1925).

[21] Note 18, *supra.*

[22] De Forest v. Meissner, *et al.,* 298 Fed. 1006, 54 App. D.C. 391 (1924).

[23] Note 18, *supra.*

[24] Patents No. 1,507,016 and 1,507,017, issued Sept. 2, 1924.

[25] "Whenever a patent is refused . . . by the Court of Appeals for the District of Columbia . . . the applicant has a remedy by bill in equity; and the court . . . may adjudge that such an applicant is entitled . . . to a patent . . ."

[26] Note 18, *supra.*

[27] "Whenever there are interfering patents, any person . . . may have relief . . . by a suit in equity against the owners . . . and the court may declare either of the patents void . . ."

[28] Note 4, *supra.*

[29] De Forest Radio Co. v. Westinghouse, 13 F.2d 1014 (D.C. Penn. 1926).

[30] Morgan v. Daniels, 153 U.S. 120, 14 Sup. Ct. 34.

[31] *Air L. Rev.* 280.

there were two separate inventions, for he had filed separate applications on the radio frequency amplifier-detector and the oscillator.

The proceedings in the Delaware District Court were decided in favor of De Forest.[82]

Armstrong appealed the decision of both the Delaware and Pennsylvania District Courts. These cases, with another case of Langmuir, were argued together, and the Circuit Court, in a single opinion, affirmed in favor of De Forest.[83] In essence, the Circuit Court held that the presumption of validity which attached to the De Forest patents as a result of the proceedings in the Court of Appeals for the District of Columbia had not been overcome. The Circuit Court did not indicate that the Armstrong patent enjoyed any presumption of validity. The Supreme Court affirmed [84] on the authority of *Morgan* v. *Daniels*.[85]

One would think that the controversy was at last ended. As between Armstrong and De Forest and their respective assignees the doctrine of *res judicata* applied; however, the final episode was yet to be determined. It began when the American Telephone and Telegraph Company, the owner of the De Forest patents, sued Radio Engineering Laboratories, a small manufacturing company, for infringement of the two De Forest patents. Armstrong, determined to upset the De Forest patents, undertook to pay the expenses of the litigation. The infringement was admitted, and the defense of prior invention by Armstrong alleged. The District Court upheld the De Forest patents.[86]

The decision was reversed by the Court of Appeals.[87] The Court of Appeals took the view that the invention involved was the radio frequency regeneration circuit and that Armstrong was the first inventor of this particular circuit. The Supreme Court again granted a petition for certiorari, and after granting a petition for rehearing reversed the Court of Appeals.[88]

The evidence produced during the various phases of the regeneration controversy was essentially the same. In an effort to establish a date of conception Armstrong testified as follows:[89]

> Q. 16. Will you please fix as closely as you can the dates of these occurrences?
> A. I showed the apparatus to my father within a very few days after the invention was made; that was about the first of October, 1912. As nearly as I recollect I told Mr. Burgi of my work within a month of that date . . . The disclosure to my uncle occurred during the Christmas holidays of 1912.
> Q. 17. Please state whether or not you made a drawing of the connections and had it witnessed by a notary?
> A. I did. Shortly after receiving this advice I drew up a sketch of the best circuit

[82] Meissner, *et al.*, v. De Forest Radio Tel. and Tel. Co., 18 F.2d 338 (D.C.Del. 1927).
[83] Westinghouse v. De Forest Radio Tel. and Tel. Co., 21 F.2d 918 (C.C.A. 3d Cir. 1927).
[84] Langmuir, *et al.* v. De Forest, *et al.*, 278 U.S. 562, 49 Sup. Ct. 34 (1928).
[85] Note 30, *supra.*
[86] Radio Corporation of America, *et. al.* v. Radio Engineering Laboratories, Inc., 1 Fed. Sup. 65 (E.D.N.Y. 1932).
[87] Radio Corporation of America, *et. al.* v. Radio Engineering Laboratories, Inc., 66 F[2d] 768 (C.C.A. 2d Cir. 1933).
[88] Radio Corporation of America, *et. al.* v. Radio Engineering Laboratories, Inc., 293 U.S. 1, 55 Sup. Ct. 928 (1934).
[89] Transcripts of Records, U.S. Supreme Court Case No. 619, 1933, p. 833.

connections which I had used up to that time and had it witnessed by a notary . . . The date of this sketch was January 31st 1913.

A facsimile of the drawing [40] referred to appears as Figure 1. No written explanation of the operation or results of testing appeared on the drawing.

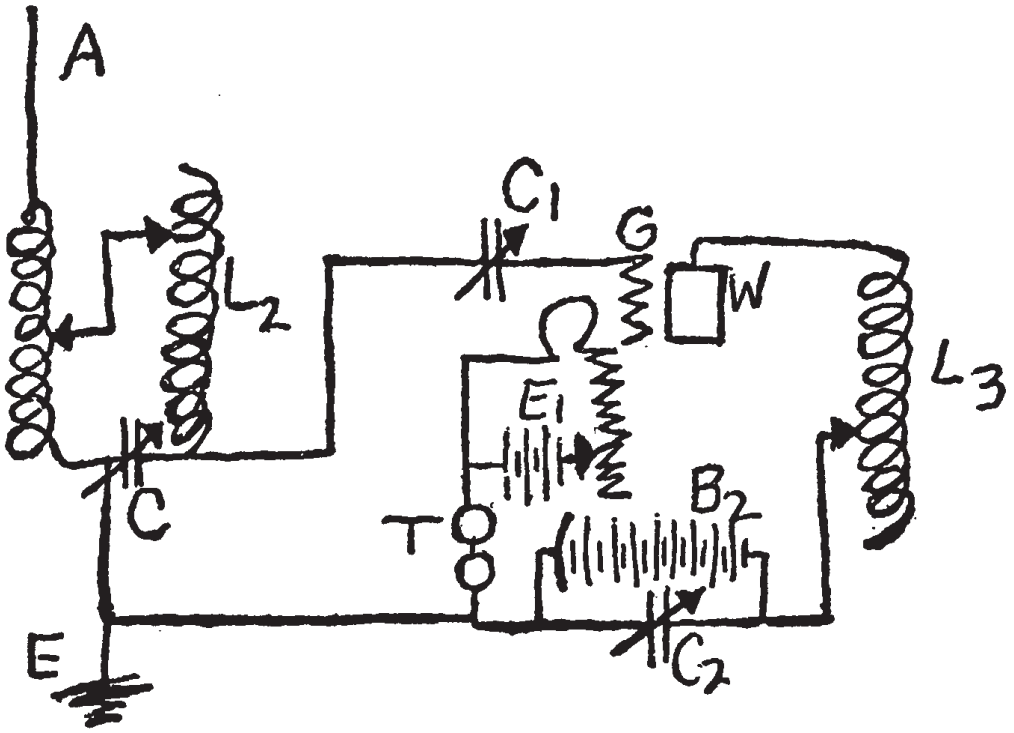

FIGURE 1. ARMSTRONG'S SKETCH OF JANUARY 31, 1913

The testimony of Armstrong relating to his drawing continued:[41]

Q. 19. Did you show the sketch to anyone else at or about this time?

A. To the best of my recollection the next man I showed it to was Mr. Frank Mason, an instructor of mine at Columbia University.

Q. 21. Please state whether or not any of these persons to whom you spoke of your work before you showed it to Mr. Mason had any knowledge of wireless, and whether you attempted to explain to any the nature of your invention?

A. None of these people had any knowledge of wireless phenomena. I did not explain except in a general way, the operation of the system to any of them.

As evidence of conception and reduction to practice by De Forest a number of notebook drawings and records of experiments were presented. On August 6, 1912, De Forest, seeking to use a dual triode tube as a repeater for audio frequency signals, interconnected the input and output circuits. A schematic drawing of this circuit was recorded in the notebook [42] of De Forest's laboratory assistant, Herbert Van Etten; see Figure 2.

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[40] *Id.* at 1419.
[41] *Id.* at 834.
[42] *Id.* at 1166.

The following text accompanied the drawing:

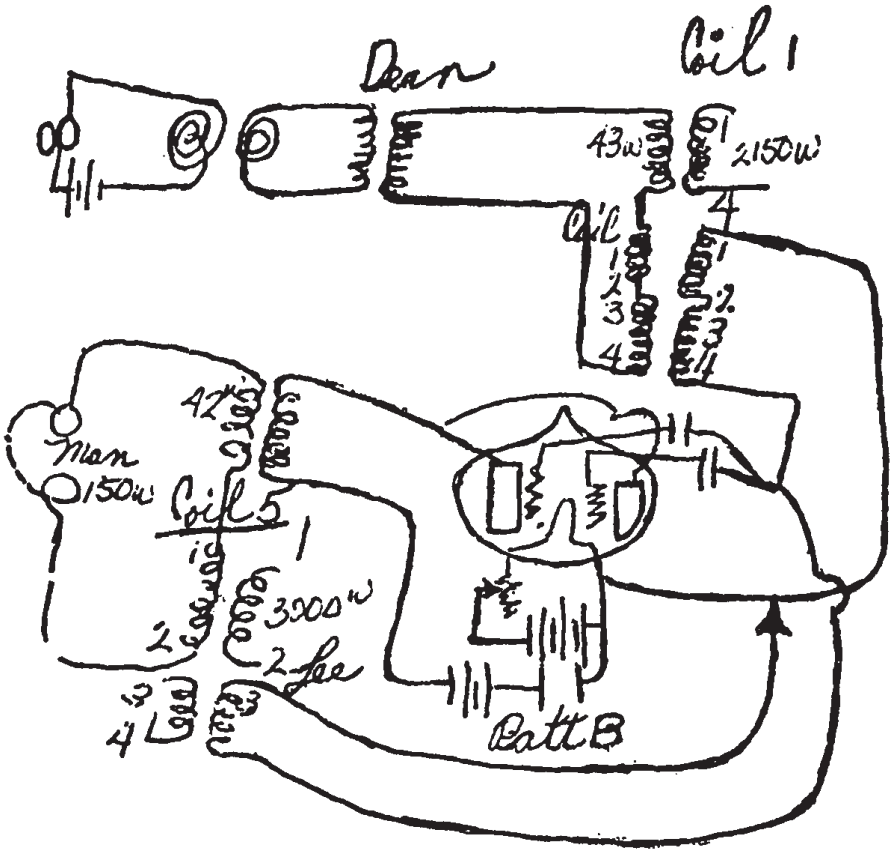

FIGURE 2. DRAWING FROM VAN ETTEN'S NOTEBOOK

> . . . tried the following circuit and found the watch ticks came thru altho they were not amplified . . . a slight loss probably. When 3-4 of coil 5 is connected as indicated to 1-4 of coil 4 get a beautiful clear tone in the phones.

On the following page of Van Etten's notebook [48] notes indicated the tone could be varied by varying the size of the B battery, and that the phenomenon was apparently similar to the howl produced in an ordinary telephone when the receiver was placed next to the transmitter.

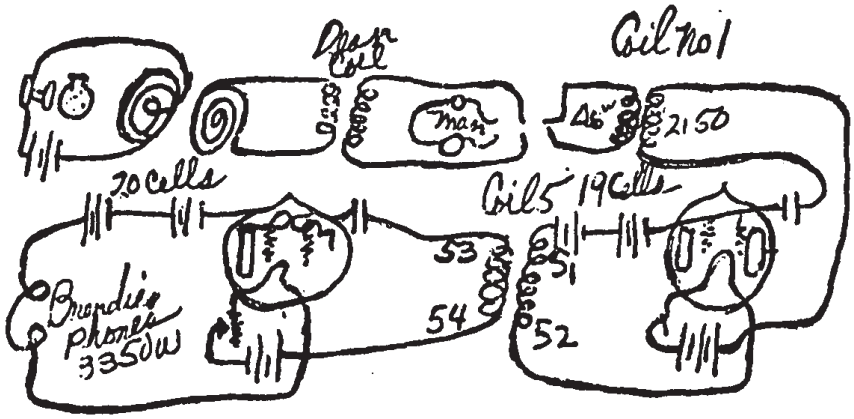

FIGURE 3. DRAWING FROM DE FOREST'S NOTEBOOK

[48] *Id.* at 1167.

A similar experiment was performed on August 29, 1912. A schematic drawing[44] of this circuit was recorded in De Forest's notebook; see Figure 3.

The following text accompanied this drawing:

> Reversing the connections to the secondary wdg. of coil #1 made all sorts of musical notes in the Brandes phones, then reversing the connections to one coil wdg. of coil 5 the musical notes are gone.

De Forest testified with respect to the events of August 1912 as follows:[45]

> Q. 17. The fundamental principle of the patent in suit state when you first became familiar with such a coupling whereby energy in the plate circuit is fed back into the grid filament circuit. With that understanding of what I mean by feed back coupling, will you please state when you first became familiar with such a coupling? [sic.]
>
> A. . . . in the summer of 1912. The first written description of work showing such a coupling occurs, so far as my notebook is concerned, under the date of August 29, 1912 . . . We observed at that time, as noted by Mr. Van Etten, that the pitch of the musical notes could be changed by putting on very small capacities, such as the capacities of one body between or by crossing either any or all of these points through small capacities.

Some questions relating to a demonstration by Armstrong of his regenerative circuit followed in which some similarities were pointed out by De Forest who continued:

> Q. 21. In other words, in the demonstration this morning, the Armstrong circuit was adjusted as described in the patent to a point below oscillations?
>
> A. Yes.
>
> Q. 22. Whereas in your circuit arrangement there described in the book, it was adjusted to obtain oscillations?
>
> A. To obtain oscillations and . . . to change the pitch of the oscillations . . .
>
> Q. 25. Was all of Van Etten's work in connection with the audion under your direction and instruction?
>
> A. Yes.
>
> Q. 42. Did you know at that time, August 6, 1912 why the audion was generating sustained electrical oscillations?
>
> A. We understood perfectly well the reason for this. The first discovery was accidental, but we at once arrived at the correct explanation of this. When the input and output circuits were associated, as I have described in connection with the August 29th sketch.
>
> Q. 45. Did you point out any specific uses to Van Etten and Logwood at that time . . .?
>
> A. On account of the small size of the output I pointed out at that time that it would be chiefly useful . . . as a generator of 500 cycle current, or as a driver where such character of variable current would be needed . . .

Some further questions were asked De Forest by the Court:[46]

> Q. 48. At that time there had been no impression on your mind as to the efficacy of this in connection with receivers?
>
> A. Not immediately at this time, but very shortly thereafter, not on the date of August 29, 1912.
>
> Q. 58. What were the next uses, or when did any other uses suggest themselves to you?
>
> A. I disclosed them to Mr. Stone in October, 1912 . . .

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[44] *Id.* at 1168.
[45] *Id.* at 727.
[46] *Id.* at 734 and 766.

Q. 68. What would be necessary to make, for example, the circuit in Van Etten's notebook generate radio frequencies rather than audio frequencies?

A. Merely the substitution of so-called radio frequency coils for the coils of high inductance . . .

Q. 156. At first, as I gather your testimony, your thought was that this was useful solely in connection with laboratory purposes.

A. That was the first thought that occurred to me after we had our demonstration in August, 1912, this oscillating audion for the production of musical notes.

Q. 167. When was it, if you can answer the question, that you are willing to say you first appreciated that the so-called feed back circuit would be useful for practical radio work?

A. Between the last of August and the last of October, 1912.

Q. 158. And was that your conviction continuously from that time on?

A. Absolutely, yes, sir.

Under cross examination De Forest testified as follows:[47]

X.Q. 176. Now what do you mean by "shortly thereafter?" I want you to say when you first realized that you could make the audion oscillate at any frequency you pleased by varying the inductance and capacity of circuits.

A. Within a few weeks thereafter.

X.Q. 177. Well before August 29th?

A. In less than two months thereafter.

X.Q. 178. Before August 29th?

A. I would not say before August 29, but I would say before October 30th.

With respect to the first use of the oscillating audion De Forest testified on cross examination as follows:[48]

X.Q. 121. When did you first successfully apply the oscillating audion to either one of the three purposes covered by this investigation?

A. In the spring of 1913 at Palo Alto, I connected the audion with a feed back circuit so as to detect by audio heterodyning the arc signals from Federal's telegraph station at South City, San Francisco . . .

X.Q. 140. This morning you testified that in the spring of 1913 at Palo Alto you first successfully applied the oscillating audion to either of the three purposes of your investigation; do you wish to correct that statement?

A. Yes . . . The production of alternating currents which were actually serviceable in radio signalling was the event I had in mind when I answered X.Q. 121.

By other testimony[49] De Forest fixed the date of this use in a radio as April 17, 1913.

It was not until March 21, 1914 that De Forest filed a patent application, after he had learned of Armstrong's work, as indicated by his own testimony:[50]

X.Q. 75. . . . In the interval between February 4th, 5th, 1914 you had learned, had you not, Dr. De Forest, that Mr. Armstrong had some sort of set-up for receiving signals at his home; that he had received signals from Honolulu . . .

A. During what interval?

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[47] *Id.* at 767.
[48] *Id.* at 163.
[49] *Id.* at 161.
[50] *Id.* at 168.

X.Q. 76. Prior to February 5, 1914?

A. I believe that is correct . . . but I knew nothing of the details. I did not know what he did at the time.

The testimony of De Forest was corroborated by Van Etten and Charles V. Logwood.[51] However, John Stone, to whom De Forest had disclosed his invention, testified as follows:[52]

Q. 16. At the time you were thoroughly conversant in the radio art and were conversant with the radio situation, were you not?

A. Yes, I think I was.

Q. 17. As an engineer appreciating these requirements, did it occur to you that this disclosure by De Forest embodied the idea of extreme or unusual value to the radio art?

A. No, I did not perceive any value.

After 14 years of litigation, we find that seven tribunals had ruled in favor of De Forest and six in favor of Armstrong. Having essentially the same evidence before them, equally competent tribunals reached different conclusions on the issue of priority of invention. All of the courts and, in particular, the two Circuit Courts seem to have been well apprised of the prior art. The major difficulty seemed to be in interpreting the complex technical subject matter in the light of the patent law, which compelled lay tribunals to make a determination of who was first to conceive the subject matter of the claims.

THE SUPERREGENERATIVE CONTROVERSY

The superheterodyne radio, as it had developed in 1920, was a very expensive and complex device. Many engineering problems needed to be solved before an inexpensive version could be developed. The regenerative receivers available were relatively inexpensive and simple, but had a tendency to "howl," that is, break into oscillations. What the radio industry appeared to need at the time was an inexpensive receiver which did not "howl."

Armstrong, while experimenting with a regenerative circuit, discovered that if means were provided to disable the regenerative circuit at a superaudible rate, it was possible to prevent the circuit from howling and still provide for amplification and detection.

A patent application on this new circuit was filed by Armstrong on June 27, 1921 and in due course a patent was granted on July 25, 1922.[53] Shortly thereafter broad claims in the patent were copied by Charles Logwood, and an interference declared by the Patent Office. Later a third party, Laurence B. Turner, was added. On opening the preliminary statements, it was found that Turner's filing date was prior to the earliest date of conception alleged by the other parties. Accordingly, priority was awarded to Turner with respect to the broad claims of Armstrong's patent.[54] In due course a patent was issued to Turner.[55]

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[51] *Id.* at 223, 273, 458, 579, 1093.

[52] *Id.* at 675.

[53] Note 6, *supra.*

[54] 319 OG 705.

[55] Patent No. 1,642,861, issued Sept. 20, 1927.

Armstrong did not suffer any financial loss as a result of this interference, for he had sold his rights on the superregenerative circuit to R.C.A. in June, 1922, for $200,000 and 60,000 shares of R.C.A. stock.[56]

THE SOCIAL AND HISTORICAL CREDIT

In spite of Armstrong's failure to retain legal credit for being the first inventor of the regenerative, superregenerative, and superheterodyne circuits, he has been given a part of the social and historical credit which he shares with others. He has also been honored by professional societies for his contributions.

Armstrong is identified as an inventor of the regenerative circuit, the superheterodyne, and superregenerative circuit in *Who's Who in America*.[57] The same publication [58] credits De Forest as an inventor of the triode tube as a radio detector, radio and telephone amplifier, and oscillator. *International Who's Who* [59] similarly credits both inventors.

The Encyclopedia Americana [60] indicates that De Forest "discovered" the oscillating properties of the audion in 1912, and that Armstrong "perfected" the regenerative circuit in 1913. It goes on to state that the circuits were similar in operation, and that after years of litigation, the Supreme Court decided in favor of De Forest. *The Encyclopedia Britannica* [61] simply reports that between 1910 and 1915 Armstrong, De Forest, Meissner, and others found special advantages in a feedback circuit which produced either regeneration or self-oscillation.

Donald McNicol, past president of the Institute of Radio Engineers, mentions both Armstrong and Logwood as contributors of the superregenerative circuit,[62] both Armstrong and Levy as inventors of the superheterodyne,[63] and De Forest and Armstrong as contributors of feedback circuits.[64] Many other authors of historical accounts of the development of the radio industry credit both inventors in these instances of dual inventions.

Armstrong, who had been awarded the Medal of Honor by the Institute of Radio Engineers in 1917 [65] for his work on the feedback, or regenerative circuit, sought to return the Medal at the National Convention of the Institute in May of 1934 as a result of his defeat in the Supreme Court. The President of the Institute, Mr. Jansky, on behalf of the Board of Directors refused to accept the Medal and quoted the substance of the citation which accompanied it:[66]

That the Medal of Honor be awarded to Edwin Howard Armstrong for his engineering

[56] Lessing, Note 6, *supra* at p. 146.
[57] *Who's Who in America* (Chicago: Who's Who, Inc. [Marquis]), XXVIII, p. 84.
[58] *Id.*, XXX, p. 693.
[59] *The International Who's Who* (18th ed.; London: Europa Publications Ltd., 1958), p. 28 and (27th ed., 1958), p. 213.
[60] *Encyclopedia Americana* (New York: Americana Corporation, 1958), XXIII, 121d.
[61] *Encyclopedia Britannica* (Chicago: Encyclopedia Britannica, Inc., 1958) VIII, p. 340H
[62] McNicol, *Radio's Conquest of Space* (New York: Murray Hill Books, Inc., 1946), p. 280.
[63] *Id.* at p. 264.
[64] *Id.* at pp. 173-184.
[65] *Proceedings of the Institute of Radio Engineers* (April 1919), v. 7, p. 96.
[66] *Proceedings of the Institute of Radio Engineers* (June 1934), v. 22, p. 812.

and scientific achievements in relation to regeneration and the generation of oscillations by vacuum tubes.

In 1940 the American Society of Mechanical Engineers awarded Armstrong the Holley Medal "for his leadership in the field of radio communication."[67]

The renowned Franklin Institute presented him with the Franklin Medal for 1941 saying:[68]

> . . . in recognition of his pioneer work in regeneration and the oscillating vacuum tube circuits, in the invention of the superheterodyne circuit, the super-regenerator, and a system of wide swing frequency modulation, each an outstanding contribution to the communication art."

The Edison Medal, given annually by the American Institute of Electrical Engineers for meritorious achievement in the electrical field, was awarded to Armstrong for the year 1942. The medal was presented with these remarks:[69]

> . . . for distinguished contributions to the art of electric communication, notably the regenerative circuit, the superheterodyne circuit, and frequency modulation.

CONCLUSION

The claims of Lessing and others that Armstrong is recognized as the "true" inventor of the superheterodyne radio, the regenerative circuit, and the super-regenerative circuit are understandable. One can hardly expect the social and historical credit to be identical with the legal credit, especially when the legal credit is clouded by divergent findings. This lack of identity does not make a legally recognized inventor any less "true" than a socially and historically recognized contributor in the same subject area.

The superheterodyne and superregenerative controversies illustrate relatively easy applications of the patent law, which provides that only the first inventor be rewarded by the grant of a patent. The regenerative controversy, on the other hand, illustrates an instance where the application is very difficult because of overlapping dates and complex technical subject matter.

The outstanding problem in the De Forest-Armstrong controversy appears to be that of recognition. It is the opinion of the author that both of these men would have fought just as hard for priority regardless of whether or not money was involved.

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[67] *Mechanical Engineering* (January 1941), v. 63, p. 61.
[68] *Franklin Institute Journal* (September 1941), v. 232, p. 260.
[69] *Electrical Engineering* (January 1943), v. 62, p. 27.

APPENDIX A

PATENTS NAMING ARMSTRONG AS INVENTOR

1,113,149	Oct. 6, 1914
1,336,378	April 6, 1920
1,342,885	June 8, 1920
1,388,441	Aug. 23, 1921
1,416,061	May 16, 1922
1,424,065	July 25, 1922
1,502,875	July 29, 1924
1,539,820	June 2, 1925
1,539,821	June 2, 1925
1,539,822	June 2, 1925
1,541,780	June 2, 1925
1,545,724	July 14, 1925
1,611,848	Dec. 21, 1926
1,675,323	July 3, 1928
1,716,573	June 11, 1929
1,941,066	Dec. 26, 1933
1,941,067	Dec. 26, 1933
1,941,068	Dec. 26, 1933
1,941,069	Dec. 26, 1933
1,941,447	Dec. 26, 1933
2,024,138	Dec. 17, 1935
2,062,074	Dec. 8, 1936
2,082,935	June 8, 1937
2,085,940	July 6, 1937
2,098,698	Nov. 9, 1937
2,104,011	Jan. 4, 1938
2,104,012	Jan. 4, 1938
2,116,501	May 10, 1938
2,116,502	May 10, 1938
2,122,401	July 5, 1938
2,130,172	Sept. 13, 1938
2,169,212	Aug. 15, 1939
2,203,712	June 11, 1940
2,215,284	Sept. 17, 1940
Re 21,660	Dec. 17, 1940
2,264,608	Dec. 2, 1941
2,275,486	Mar. 10, 1942
2,276,008	Mar. 10, 1942
2,290,159	July 21, 1942
2,295,323	Sept. 8, 1942
2,315,308	Mar. 30, 1943
2,318,137	May 4, 1943
2,323,698	July 6, 1943

APPENDIX B

SUITS FILED ON ARMSTRONG'S FREQUENCY MODULATION PATENTS

	DEFENDANT	DATE	PROCEEDING NO.	COURT
1.	Radio Corp. of America & The National Broadcasting Co.	July 22, 1948	1139 C.A.	(D.C. Del.)
2.	Allen B. Dumont Laboratories, Inc.	Dec. 17, 1953	1580 C.A.	(D. C.Del.)
3.	Philco Corporation	Dec. 17, 1953	16170 C.A.	(E.D. Penn.)
4.	Emerson Radio & Phonograph Corporation	Dec. 21, 1953	90–142 Civ.	(S.D. N.Y.)
	(Consent Judgment, Jan. 28, 1960)			
5.	Radio and Television, Inc.	Jan. 4, 1954	90–212 Civ.	(S.D. N.Y.)
	(Dismissed on Stipulation Sept. 5, 1956)			
6.	Sylvania Electric Products, Inc.	Jan. 6, 1954	54–6–S	(D.C. Mass.)
7.	Motorola, Inc.	Jan. 6, 1954	54C19	(N.D. Ill.)
8.	The Radio Craftsmen, Inc.	Jan. 6, 1954	54C20	(N.D. Ill.)
	(Dismissed on Stipulation Sept. 14, 1955)			
9.	Sentinel Radio Corporation	Jan. 6, 1954	54C21	(N.D. Ill.)
	(Dismissed on Stipulation April 2, 1956)			
10.	Wells-Gardner & Co.	Jan. 6, 1954	54C22	(N.D. Ill.)
	(Dismissed on Stipulation July 20, 1955)			
11.	Gilfellan Bros., Inc.	Jan. 7, 1954	16, 169T	(S.D. Cal.)
12.	Admiral Corporation	Jan. 7, 1954	1586 C.A.	(D.C. Del.)
13.	Avco Manufacturing Corporation	Jan. 7, 1954	1587 C.A.	(D.C. Del.)
14.	Arvin Industries, Inc.	Jan. 12, 1954	3635 Civ.	(S.D. Ind.)
	(Dismissed on Stipulation April 23, 1956)			
15.	Hoffman Radio Corporation	Jan. 7, 1954	16, 170T	(S.D. Cal.)
16.	Packard-Bell Company	Jan. 7, 1954	16, 171T	(S.D. Cal.)
17.	Philharmonic Radio and Television Corporation	Aug. 5, 1955	102–294	(S.D. N.Y.)
18.	Bendix Aviation Corporation	Aug. 8, 1955	1741	(D.C. Del.)
19.	International Telephone & Telegraph Corporation	Aug. 9, 1955	8427 Civ.	(D.C. Md.)
20.	Fada Radio & Electric Co., Inc.	Aug. 11, 1955	102–343 Civ.	(S.D. N.Y.)